

Non-Contrast MRA

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Introduction

In MR angiography (MRA), techniques are mainly divided into contrast-enhanced MRA and non-contrast MRA. Various non-contrast MRA techniques are clinically useful and widely used in routine examinations, such as 3D TOF [1] in intracranial region, phase shift [2] for flow quantification, arterial spin labeling [3,4] in pulmonary vessels [5,6], and balanced SSFP [7] in bright blood cardiac cine. In this paper, flow-spoiled fresh-blood imaging (FS-FBI) [8] as a non-contrast peripheral MRA technique is described in a technical format in regards to its clinical utility to distinguish arterial flow from venous flow.

Technical Aspects of Flow-spoiled Fresh Blood Imaging (FS-FBI)

The value of flow-spoiled fresh-blood imaging (FS-FBI) in peripheral vessels is that the pulsatile flow differences during diastole and systole are used to differentiate arteries from veins. Since venous flow is unchanged throughout the cardiac cycle, subtraction of systole from diastole provides only arterial information. Therefore, ECG- or peripheral pulse-gating (PPG) is applied in 3D half-Fourier FSE to trigger during diastole to depict bright blood and during systole to depict black blood. In half-Fourier FSE, a short echo train spacing (ETS) or inter-echo spacing is used to reduce the T2 blurring effects associated with this FSE technique and

sharpen edge detail of the imaged vasculature. For variances in flow speed for upper (iliac), middle (thigh), and lower (calf), an appropriate flow-compensation or flow-spoiler gradient pulse in the read-out (RO) direction was applied accordingly. Respectively, in the iliac region, a partial flow-compensation of -10% (as the start of the RO gradient to the center of echo as 100%) was implemented. In the thigh region, no spoiler was applied. In the calf region a partial flow-spoiler pulse of an area of about +10% was used. To increase depiction of slower flow in the foot and ankle region, a stronger flow-spoiler gradient pulse of +30% and +20%, respectively, was used to create dark blood during systolic flow. Of note, a flow-spoiler pulse is ineffective for suppressing stationary tissue.

Prior to the 3D data acquisition, ECG or PPG timing was measured using ECG-prep scan [9]. ECG-prep scan acquires a single slice in multiple phases in order to determine the appropriate diastolic and systolic delay times. ECG-prep scan parameters were as follows: TR/TE_{eff} of 3 R-R intervals/80 ms, echo train spacing (ETS) of 5 ms, matrix of 128x256, TI of 130 ms, number of acquisitions (NAQ) of 1, slice thickness of 70-80 mm, field of view (FOV) of 40x40 cm, parallel imaging reduction factor of 2.0, number of shots 1, about 8 phase images starting from 0 ms of an R wave with an increment of 100 ms, and a total acquisition time of about 24 seconds, depending upon the cardiac rate. Once the systolic and diastolic triggering delay times are determined, the continuous scan of systolic and diastolic triggered 3D acquisition was acquired. The parameters for the 3D acquisition were as follows: TR/TE_{eff} of 3 R-R intervals/ 80 ms, ETS of 5 ms, TI of 130 msec, NAQ of 1, matrix of 256x256, slice thickness of 3 to 5 mm (interpolated to 512x512, 1.5-2.5

mm thick slice), FOV of 40x40 cm, number of shots 2, number of slice encodings 25 to 35, parallel imaging reduction factor of 2.0, and a total acquisition time of 3 to 4 min. Notes that actual single shot time of 3D acquisition (256 lines with 2 shots) was the same was that of ECG-prep scan (128 lines with 1 shot).

After continuous 3D systolic-diastolic acquisition, presetting of auto-subtraction of diastole from systole, followed by a maximum intensity processing (MIP), yielded the arterial images. In order to demonstrate venous flow additional subtraction of subtracted source images from systolic images was completed. The original systolic images yielded black blood arteries; however, some smaller branch arteries with slower flow yielded a bright blood appearance. Therefore, the additional subtraction of subtracted images, containing only arteries, from systole gives completely non-arterial images. Since the venous images are obtained after the double subtraction, background signals and long T2 components are depicted.

Results and Discussions

From the ECG-prep scan, one determines the diastolic- and systolic-triggering times. Because an inversion pulse (TI) of 130 ms is used to saturate fat signals, systolic-triggering delay time is about 100 ms, in which single-shot images provide black blood arteries. It is easier to determine systolic-triggering since the arteries appear black than determining the appropriate diastolic-triggering delay time because many phases demonstrate arteries with bright blood. By subtraction of the systolic phase from all other phases acquired in the ECG prep scan the bright blood arteries are easily distinguished from veins. Once triggering delay times are

determined, the same delay times are used for all regions. In the event PPG is used rather than ECG, an extended pulse delay of about 300 ms is required to consider. Therefore, normal systolic phase becomes 400 ms, which is also confirmed by seeing the black blood arteries. PPG diastolic delay time is determined by subtraction of the systolic phase from all other phases acquired within the prep sequence as is done with the ECG scan.

Presetting of flow-spoiler pulses for 3 stations (iliac -10%, thigh 0%, and calf +10%) gives good approximation of spoiler strength in normal volunteers. For elder patients, the 3 station presetting of iliac 0, thigh +5%, and calf +15% was used. When flow is too fast, especially in the iliac region, N/2 artifacts appear in the right-left (RL) phase-encode (PE) direction. In order to reduce N/2 artifacts, a partial flow compensation pulse (spoiler pulse of -10%) is applied.

Most peripheral vessels run superior to inferior; however, some torturous vessels are oriented in parallel to the PE direction. Intrinsic dephasing effects of the longer TE_{eff} increased the signal difference between the systolic and diastolic triggered images. This is due to the longer echo train length (ETL) which gives stronger dephasing in the PE direction than a short ETL, since near centric k space ordering is used in the sequence. In addition, the flow-spoiler pulse in the PE direction helps delineation of vessels oriented in the PE direction [10].

Continuous diastole-systole acquisition gives less miss-registration errors, as compared to the separate scans of diastole and systole. Patients tend to immobilize during a single-scan acquisition. This single acquisition feature helps not only diastole-systole subtraction but allows less operational errors.

Conclusions

Technical aspect of FS-FBI in separation of arteries from veins is presented using the flow-spoiler gradient pulse in ECG- or PPG-triggered half Fourier FSE. The method shows great promise, even for the evaluation of extremely slow-flow runoffs. Clinical evaluations of the technique in patients with arterial and venous diseases are presented elsewhere [11-14].

References

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